That instrument, the original meridian circle mounted by Dr. GOULD, has an aperture of 4.9 inches only, and a twelfth magnitude star should be visible with its use in a dark field. The illumination in the field of a meridian circle cannot usually be as delicately adapted to the sight as in micrometer work with an equatorial. Tenth-magnitude stars can be observed, but the difficulties are sensible, and the uncertainty of the scale at the lower end of the visual *Durchmusterung* must be considered.

Astronomical photographs can go as far as desired, with sufficiently long exposures. But the unequal distribution of the faintest grades, published in the Cape *Durchmusterung,* raises the question of the actual brightness of the corresponding stars. Below ninth magnitude there are estimates extending over a considerable range, but so few proportionately of each grade that it would be hard to say what low grade is completely included. The colors of the faint stars are usually considered to show but little variety to account for this condition.

March 14, 1913.

THE INFLUENCE OF GRAVITATION ON LIGHT.

BY HEBER D. CURTIS.

In *Annalen der Physik,* **35,** 898, 1911, Dr. A. EINSTEIN postulates the hypothesis that a ray of light will suffer deflection, or quasi-refraction, when passing through a powerful field of gravitation. This hypothesis is a result of the theory of relativity,[1] but from what we know of the behavior of light when passing through matter or a strong magnetic field, it is perhaps not inherently impossible that some such action should exist independently of the requirements of the theory of relativity. Physicists, it may be said parenthetically, are to-day divided into two warring camps on the subject of the theory of relativity, and whether it will ever become generally accepted is an open question, particularly as EINSTEIN has recently been forced to make certain rather radical alterations in the theory as originally stated by him. EINSTEIN puts forward

[1] *Publications, A. S. P.,* **23,** 219, 1911.

the theory of the bending of light rays by gravitation with some reservation, but closes his paper with the words: "It is greatly to be desired that astronomers should undertake this investigation, although the foregoing reasoning may prove to be insufficiently founded or even entirely illusory. For, aside from any theory, the question must be considered, whether with our present resources an influence of the gravitation field on the propagation of light can be established."

EINSTEIN points out that we have a way to test this hypothesis by investigating the positions of stars seen near the Sun at the time of total solar eclipse. His formula (true to the first order only) for the deviation suffered by a ray of light passing through a gravitational field is,—

$$a = \frac{2kM}{c^2 D},$$

where k is the gravitation constant; M the mass of the attracting body; c the velocity of light, and D the distance from the path of the ray to the center of attraction. Adopting 6.14×10^{27} grams as the mass of the Earth (mean density 5.67); $g = 981^{cm}$; Sun's mass : Earth's mass = 330,000 : 1; and $695{,}500^{km}$ as the radius of the Sun, a ray of light passing close to the limb of the Sun should, in accordance with the formula given above, suffer a deflection toward the Sun of about 0".86, the apparent angular distance of the star from the Sun's center being *increased* by this amount. The effect varies inversely as the distance of the ray-path from the center of the Sun; if the star's distance, D', from the Sun's center is expressed in minutes of arc, the effect will be given by, $a'' = 13.8/D'$.

The *doubled* effect, for pairs of stars situated on opposite sides of the Sun, will be as follows, the distances being expressed, for convenience, in minutes of arc from the *limb* of the Sun:—

Distances from Sun's Limb.	$2a$
5′	1″.32
10	1 .06
20	0 .76
30	0 .60
40	0 .50
50	0 .42
60	0 .36

These doubled effects are small, but not beyond the reach of measurement on plates taken with instruments of fairly long focus.

Probably the only observational material at present available to test the truth or falsity of this hypothesis is that afforded by the series of plates taken in the searches for intramercurial planets at the Lick Observatory-Crocker Eclipse Stations in 1901, 1905, and 1908. These plates were taken with lenses of three inches aperture and eleven feet four inches focal length, and copies on glass of certain of these negatives have been sent to Dr. FREUNDLICH, of Berlin, for measurement in connection with this problem. Unfortunately, it seemed evident in advance that no results of value could be secured from these plates, and Dr. FREUNDLICH has since abandoned the attempt to measure any deflection effect from them. These intramercurial search plates were taken for an entirely different purpose; very large plates were used, and the image of the eclipsed Sun is on the very edge of these large plates, with the result that the distortion not only cuts out the fainter star images, but leaves any visible images near the Sun fan-shaped, so that it is impossible to measure these with any accuracy. Moreover, these plates were taken with the driving clock rated to solar rather than sidereal time; this rating would cause the star images to show a trail of about seven seconds of arc in an exposure of three minutes. For the purposes of this investigation the image of the Sun should be central on the plate, the mounting as rigid as possible, and the driving clock rated on stars, instead of on the Sun. Under the best conditions exposures of two to three minutes should then show sharp images of many stars as faint as magnitude 9.5.

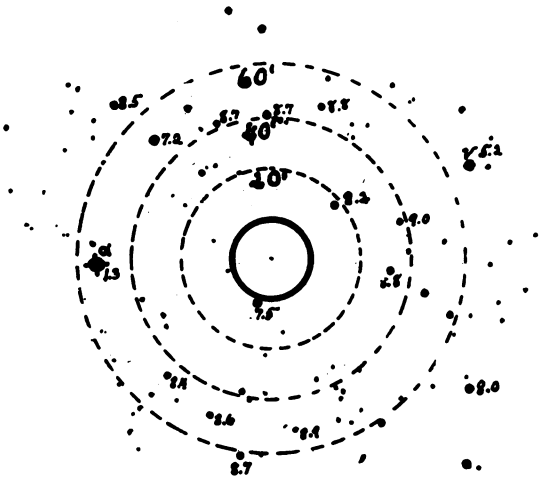
I have carefully examined the intramercurial plates taken at Flint Island in 1908, in the effort to determine the limiting factors for measureable star images in terms of magnitude and distance from the Sun's limb. The distance of the image of the Sun from the center of the plate, mentioned above, and the fact that these negatives show two images of each star, makes a definite statement difficult, but I would estimate, somewhat at a venture, that the limit of visibility of star images

with Sun central on plate, images sharp, sky clear, and exposures two minutes in length, would be,—

Magnitude 7.5, visible to 15′ from Sun's limb.
" 8.5, " " 25′ " " "

These limits might be somewhat smaller for images favorably situated outside of streamers or stronger regions of the corona.

For the Russian eclipse of August 20-21, 1914, the maximum duration of which will be two minutes and fourteen seconds, the conditions for testing this problem will be about as represented in the accompanying cut. The magnitudes of only the



STARS NEAR SUN.
Eclipse of August 20-21, 1914.

brighter B. D. stars are given, and the dotted circles are drawn at distances of 20, 40, and 60 minutes of arc from the Sun's limb. *Regulus* and *ν Leonis* are fairly favorably placed; these two stars should show an apparent increase of about 0″.35 in distance, but the great brilliancy of *Regulus* would operate to make the measures on its image subject to large errors. There is quite a favorable arrangement of fainter stars symmetrically placed about the Sun. Most of these should show distinctly

if the following were perfect, and *Regulus* would make an excellent guiding star for this purpose, though it would doubtless be better to install an electrical clock-control, and omit all attempts at guiding by hand. At least four lenses should be used, with chart plates of this region made in advance at approximately the altitude which this region would have at the time of the eclipse. Star plates should also be taken on one or two nights immediately preceding the eclipse as a control on the scale value of the plates.

From EINSTEIN'S formula the effect for *Jupiter* would be only about one one-hundredth of that caused by the Sun; in occultations by the Moon the effect would be entirely insensible, amounting to only one one-hundred-thousandth of a second of arc.

A CORRECTION.

In the February number of these *Publications* (page 52) a note was printed to the effect that the great disk of glass for the 100-inch reflector for Mount Wilson had finally been rejected as useless for the purpose. This note was based upon a similar one which appeared in *Popular Astronomy.*

It is a great pleasure to be able to correct this statement. A personal letter from Mr. WALTER S. ADAMS says that, while "the first tests showed quite an unsatisfactory figure," in that the figure of the glass did not rotate with the disk when it was rotated, indicating "an apparent bending of the glass unequally along two diameters at right angles to one another," later experiments have located the source of the difficulty in the edge-support. The "last tests proved conclusively," Mr. ADAMS continues, "that when the glass is properly supported the figure rotates perfectly with the disk. In view of these tests we have already accepted the disk and made payment for it, and are going forward with our plans on the dome and mounting of the telescope."

This will be good news to astronomers the world over, and they will all unite with us in hearty congratulations to the Solar Observatory staff upon this successful outcome.

THE COMMITTEE ON PUBLICATION.